A Relative Study on Predicting Agricultural Productivity Using Machine Learning

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

by

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DECLARATION BY THE SCHOLAR

I hereby declare that the short synopsis entitled **A Relative Study on Predicting Agricultural Productivity Using Machine Learning** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of Computer Science & Technology under the School of Engineering of Manav Rachna University, Faridabad during the academic year 2024-2025

It is the work that is expected to be carried out under the supervision of Dr. Abhishek Saxena.

Further, it is declared that the short synopsis is within the plagiarism limit and copy of the same is attached as per the University norms.

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CERTIFICATE BY SUPERVISOR

This is to certify that, the short synopsis entitled **A Relative Study on Predicting Agricultural Productivity Using Machine Learning** is an original piece of work done by research scholar PRIYA BHATNAGAR under the supervision of Dr Abhishek Saxena for the degree of Doctor of Philosophy in the Department of Computer Science & Technology under the School of Engineering of Manav Rachna University, Faridabad during the academic year 2024-2025.

Further, it is certified that the short synopsis is within the plagiarism limit and a copy of the same is attached as per the University norms.

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ABSTRACT

India is country who is deeply rooted in its history and culture and whose economy is majorly depends on our agriculture. In recent years we have observed a significant improvement in terms of technologies in agriculture. These latest modern cutting-edge technologies are making tremendous effects on our agriculture systems to make them an automated system. This automation in agriculture system triggers the use of new trending technologies like data analytics, sensors, robots, artificial intelligence (AI), machine learning (ML), and deep learning (DL). The use of these cutting-edge technologies enhances and simplifies various agricultural operations by adopting new methods in place of traditional agricultural methods. This leads to higher efficiency, more crop yields, and better resource utilization. There are many challenges that our agriculture sector is facing due to certain conditions. Few of them includes how to make accurate predictions for productivity based on factors affecting it, how to monitor soil degradation, socioeconomic reasons, change in climate circumstances, water shortages, etc. This short synopsis delves into the realm of forecasting the productivity of Indian agriculture using various factors affecting it with the help of ML/ DL, highlighting its advantages, key characteristics, and difficulties for a sustainable and effective agricultural system.

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1. Introduction

Agriculture is an excellent basis for the Indian economy, is the world's second-biggest (2nd-biggest) agricultural expanse, and supports around half of the country's population. In recent decades, a revolution has been seen in the agricultural sector in India for its development. Agricultural productivity (quantitatively and qualitatively), is dependent on various conditions of climate and weather like temperature, humidity, wind speed, rainfall, etc. There conditions and factors affect productivity and have an impact on decision-making abilities of the farmer. If the precise predictions can be possible with the of new techniques then the decision-making ability can be improved. Due to latest technologies like ML/DL classification methods, Indian agriculture has the potential to revolutionize prediction accuracy and output for a more detailed understanding of crop quality and other requirements (Sanga et al., 2021; wikipedia, 2023).

Figure 1. Technological crop monitoring (Jyothi Sharma, 2022)

Automation is required to classify the factors affecting Indian agriculture, which can help in better prediction and productivity. It enhances our understanding and decreases the time spent on the prediction of the crop and soil quality about the production of particular crops. Farmers can change their operations strategy with the help of automation. This change will help us to create a strong auto-agricultural system that will increase farmers' incomes and year-round employment. Overall, smart day-to-day agriculture operations, planning, monitoring, and controlling are possible with automation in agriculture systems with cutting-edge technologies (Ancín et al., 2022; Aworka et al., 2022; Tirkey et al., 2023).

In general Government agencies gather meteorological data from satellites or various weather stations but in smaller agricultural sectors, particularly in rural areas data is gathered manually. After that, some standard statistical algorithms are applied to analyze these data for predictions using basic Excel tools.

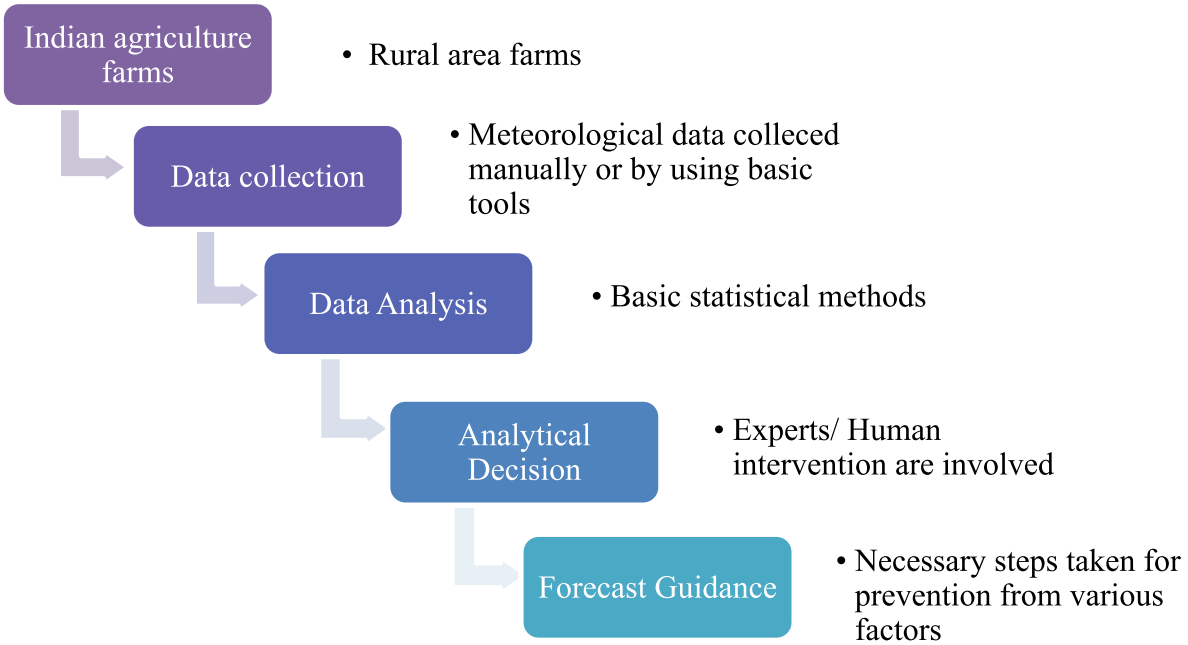
Indian agriculture farms
• Rural area farms
Data collection
• Meteorological data colleced manually or by using basic tools
Data Analysis
• Basic statistical methods
Analytical Decision
• Experts/ Human intervention are involved
Forecast Guidance
• Necessary steps taken for prevention from various factors

Figure 2. The standard approach of agriculture automation system

2. Literature Review

Researcher (Poornima et al., 2023), demonstrated that droughts and precipitation conditions are accurately predicted by the LSTM model. It shows a 0.04% yearly drop in annual rainfall. According to the data, India has had frequent mild to moderate droughts, especially since 1980. Since the rainfall prediction for the year 2021 was made with a stated accuracy of 99.46%, the predicted results agree well with actual observations.

(Padulano et al., 2023), discussed the use of an empirical model to calculate rainfall erosivity in the research by incorporating sub-hourly rain measurement readings from Italy's 171 rain gauges. The method equation is purposefully kept straightforward to highlight the importance of precipitation and its many effects throughout the year.

(Hunasigi et al., 2023), developed 8 models using meteorological data collected from Dapoli, Maharashtra, India. The study used a multilayer-perceptron ANN to predict precipitation and reference evapotranspiration (ETo) for crops. Six climate factors are entered into the models. Indicating reliable predictions, they show strong correlation coefficients (0.900 to 0.957) and low root mse values (0.543 to 22.057).

(Nigam & Srivastava, 2023), developed CNN-LSTM and LSTM-LSTM hybrid DL models for forecasting traffic stream characteristics in unfavorable climate circumstances, including rain, which affect road capacity and driver mobility. The models try to account for both short-term and long-term effects of weather on traffic. A soft spatial and temporal threshold mechanism is suggested to accomplish this. The trials show that combining traffic and rainfall data enhances prediction precision. Intelligent Transportation Systems may benefit from this research's findings, which improve traffic forecasting in bad weather.

In another paper, researchers (John & Nagaraj, 2023), implemented advanced machine learning methods and feature reduction tactics to take on the difficult problem of flood prediction. The research proposes Improved Principal Component Analysis (i-PCA) in combination with a 1D-CNN model for flood forecasting by examining daily and monthly

rainfall data for Kerala state spanning more than a century. The trials show that this strategy works since it achieves an amazing accuracy rate of 94.24%, outperforming traditional methods by 8%. The supervised learning component of the i-PCA provides experimental guidance for feature extraction, improving prediction accuracy and enabling more accurate decision-making in disaster management systems. This model may be further optimized in the future for quicker and more accurate flood predictions.

Researcher (Martinez et al., 2022), explained that the occurrence and strength of rainy days during the early and late seasons (ERS and LRS), as well as the extent of the droughts in Mid-Summer (MSD), are just a few of the numerous rainfall features that are examined using canonical correlation analysis (CCA) to see how effectively the forecast is able to predict them. The North American Multi-Model Ensemble (NMME) and ERA-Interim dataset's predictor fields are both used.

In another paper, researcher (Diaz-Gonzalez et al., 2022), employed a methodology that involves the use of advanced statistical techniques like PCA, redundancy analysis, and discriminant analysis to streamline soil data for better quality assessment of soil.

(Feng et al., 2021), compared the implications of four significant cyclones on woodlands in various regions using ML methods and remote sensing data. With wind speed, height, and pre-disturbance vegetation state emerging as significant predictors, it underlined the significance of weather variables, topographical features, and woodland characteristics in forecasting tree damage due to cyclones. Machine learning models had limitations in predicting the effect of unseen cyclones.

In one of the papers, (Yan et al., 2021), proposed an approach for large-scale crop mapping utilizing discrete grids and machine learning. It overcomes issues like sparse sampling and a lack of spatiotemporal information in satellite data. The technique improves both the spatial and temporal coverage by merging Sentinel-2 and GaoFen-1 satellite data. It resolves problems with sparse samples by using a discrete grid framework and data augmentation techniques. This framework's machine-learning techniques greatly increase processing speed

and crop categorization precision. The technique was tested in Northeast China's Sanjiang Plain, where crop mapping for 2017 and 2018 was completed with great accuracy (up to 88%). This strategy shows potential for global large-scale crop classification, assisting research on land use and food security.

(Alibabaei et al., 2021), investigated the use of DL, specifically LSTM and GRU models in order to forecast agricultural yields using climatic data and irrigation schedules. These models' accuracy in capturing the intricate connections between climatic factors, irrigation, and crop yields was tested on tomato and potato crops in Portugal. In comparison to other models, the Bidirectional LSTM (BLSTM) model performed best, obtaining high accuracy with R^2 scores ranging from 0.97 to 0.99. These results show how deep learning models may be used to optimize irrigation control and lower energy use in agriculture, hence improving food security and resource sustainability.

(Suparta & Samah, 2020), applied the Adaptive NeuroFuzzy Inference System (ANFIS) to estimate rainfall for South Tangerang, Indonesia. The plan aims to deal with the flooding problems brought on by the excessive rainfall in this fast-growing city. The ANFIS model, integrating diverse input structures and membership methods, successfully predicted rainfall with an amazing 80% accuracy over six years of monthly rainfall data. The study highlights the significance of complete and non-extreme time series data for precise forecasts and advises future research, particularly in urban flood control, to look into correlations between rainfall and variables like temperature and humidity.

(Van et al., 2020), presented that Machine learning approaches are useful for the challenging problem of simulating rainfall-runoff, which is complicated by complex interactions between the water cycle and geophysical factors. In order to estimate rainfall runoff, this paper offers a unique 1D-CNN with ReLU activation. In order to quickly analyze data and take advantage of correlations in multivariate time series, the model uses parallel convolutional filters. The CNN beats conventional models and marginally exceeds long short-term memory (LSTM) models when tested against measured data from the Vietnamese Mekong Delta. The CNN is a possible substitute for regression-type issues in water resource management due to its

success in learning dependencies, efficiency, and independence from large historical data sets.

(Yang et al., 2019), focused on the assessment and advancement of flood simulations based on the global hydrological model. The researchers analyzed observed data from 1032 gauging stations for the years 1971 to 2010 with flood simulations from five GHMs. They discovered that GHMs struggle with timing precision, particularly when operating in various temperature zones, yet perform relatively well during peak discharge. The study used a hybrid physics-machine learning framework and presented an ML technique termed long short-term memory units to address this. The findings show that the accuracy of flood simulation is greatly improved by the hybrid technique, particularly when considering peak discharge.

(Dash et al., 2018), compared the effectiveness of three AI techniques (KNN, ELM, and ANN) for the data received from Kerala, India from 2011 to 2016. The results show that all three strategies perform quite well, with the extreme learning machine technique beating both K-nearest neighbor and artificial neural network.

(Kashiwao et al., 2017), proposed a system using ANN for predicting localized precipitation that automatically downloads meteorological data from the source, in particular data from the Japan Meteorological Agency. In order to relate the performance of two ANN models, a multi-layer perceptron, and a radial basis function network, rainfall was predicted in various parts of Japan. While the MLP performed better than the RBFN at predicting rainfall, the JMA still surpassed it. With a high caching rate, the system also showed the ability to reliably forecast summertime rainfall in Tokyo.

(Shrestha et al., 2017), calculated the precision of two (2) satellite-based precipitation products, CHIRP and CHIRPS, in the Koshi basin of Nepal. CHIRPS performs better overall, although CHIRP is more accurate after 1992, according to the research, which also shows that the accuracy of these products varies with elevation. Accuracy in higher-elevation locations is greatly increased by physiographic region-specific bias adjustment. The analysis

also identifies variations in drought severity based on the two CHG datasets for the full-time period, but these differences disappear when data from after 1992 are included.

(Singh & Singh, 2017), offered a Genetic Algorithm and Radial Basis Function Neural network-based semi-supervised technique for satellite image categorization. RBFNN is a good choice for satellite photos because of its capacity to generalize findings and handle noise while addressing issues like mixed pixels and managing large amounts of image data. The technique uses spectral indices for seed selection and generalized additive modeling (GA) for network training, and it successfully classifies Landsat 8 OLI photos of Dongting Lake, particularly for identifying flooded regions. High precision and efficiency in comparison analyses validate the method's efficacy.

In another research (Wichitarapongsakun et al., 2016), researcher revealed that with a mean percentage error of 28%, Simple Exponential Smoothing outperformed the other two Time Series Prediction models used to predict rainfall. The Sakae Krang River basin's meteorological drought from the year 1970 to 2014 showed no discernible trend, according to an examination of drought severity using the Standardized Precipitation Index. Some subbasins in 2015 were subject to light to moderate drought conditions.

Paper (Sellam & Poovammal, 2016), examined how crop output prediction is affected by environmental factors including Area under Cultivation (AUC), Food Price Index (FPI), and Annual Rainfall (AR). The study examines these components over a ten-year span from 1990 to 2000 using regression analysis (RA), a multivariate approach. Crop yield is the linear regression (LR) response variable, which establishes correlations between the explanatory variables (AR, AUC, and FPI). An R2 value of 0.7 indicates that AR, AUC, and FPI jointly impact crop production by around 70%. For a more thorough crop production estimate, this research indicates the possible expansion to incorporate additional components including Minimum Support Price (MSP), meteorological conditions, and soil characteristics.

(Mohor et al., 2015), researched the effect of change in climate on the hydrological regime and hydropower production. The forecasts from many climate models are used to evaluate

the basin's susceptibility to climate change. The results of the study show a decline in flow, lengthened dry seasons, and greater susceptibility to variations in precipitation. The performance of several hydropower plant designs under different climatic scenarios reveals a decrease in yearly energy output as a result of shifting precipitation patterns and capacity restrictions.

(Cheong, 2012), created a support system to control the hazards of a flood disaster in Korea. It integrates a numerical flood simulation model in three dimensions with spatial data, such as construction and population statistics. The system's accuracy in predicting flooding and damage during testing in the flood-prone Munsan City area shows its potential for reducing flood-related effects and improving disaster management.

2.1. Literature Gap

Despite the notable implementation of DL and ML algorithms in agriculture automation systems, literature shows that most of the existing methods only focus on crop yield production and fail to analyze which agro-climatic factor influences agriculture productivity. After doing the thorough research we found that there is a very small amount of work has been done for the rural area agriculture automation. So, by this work our main intention and focus is to do the comparative analysis for the productivity of one of the rural areas of Chhattisgarh, India.

3. Description of Broad Area

3.1. Machine Learning

There are various agriculture-based applications implemented using ML (subset of AI), to enhance crop yields, sustainability, resource management, and better predictions (van Klompenburg et al., 2020). In these applications various ML approaches are used to provide useful information and insights from the data gathered from various weather stations, satellites and sensors, related to crop health, disease detection, and ideal planting times. For productivity estimation, predictive modeling is one of the most useful techniques in agriculture. Therefore, latest technologies like, ML are very essential for the overall growth as it facilitates better decision-making ability, effective agricultural production, and environment friendly methods (Dey, n.d.; Fradkov, 2020; Hay Chung et al., 2021).

3.2. Machine Learning Algorithms

There are several ML algorithms researchers have used in agriculture applications. Table 1 displays the list of ML methods that can be used for forecasting the productivity of the agriculture sector in terms of quality and quantity based on various factors (Çelik, 2018; Rahman et al., 2022; Ridwan et al., 2021; Sarker, 2021; van Klompenburg et al., 2020).

K-Nearest Neighbor
Linear Regression
Naive Bayes
Principal Component Analysis
Random Forest
Linear Regression
Support Vector Machine
Decision Trees
K-Means
Canonical Correlation Analysis

Table 1. ML algorithms

3.3. Deep Learning

DL is also a game changer technology for agriculture sector applications for better predictions. It uses multiple layers for processing, which has more complex structures to reflect elevated abstractions in data. It has the potential to change how crops can be managed, forecast productivity, how to control pests, anticipate yields, and ensure the sustainability of agriculture (Durai & Shamili, 2022; Nguyen et al., 2020; Sharma et al., 2021).

3.4. Deep Learning Algorithms

Various DL algorithms used by researchers that are useful in predicting agriculture productivity are listed in Table 2 (Alzubaidi et al., 2021; Ma & Mei, 2021; Wambugu et al., 2021; Elavarasan & Durairaj Vincent, 2020).

Convolutional Neural Networks
Residual Network
Visual Geometry Group
Recurrent Neural Networks
Long Short-Term Memory
AlexNet
GoogLeNet
ImageNet

Table 2. DL algorithms

4. Description of Topic

The Title – "*A Relative Study on Predicting Agricultural Productivity Using Machine Learning*" is selected to provide digitization in Indian agricultural industries with the help of machine learning techniques. Proper automated systems can help remove conflicts in decision-making processes among various industries. Traditional methods used for analysis of data and forecasting may not give the highest precision levels and also it is possible that it consumes more time. Therefore, it is necessary to make use of current cutting-edge technologies like ML/DL for the improvement of result precision and time consumed. In agriculture, weather and climate conditions, soil properties, fertilizer uses, and variety of seed influence its productivity. Therefore, to make appropriate precautions and immediate decisions to enhance the productivity, accurate forecasting is needed. This allows farmers to take necessary measures to prevent their harvests to reduce agricultural losses, such as changing planting schedules, putting irrigation in place, or even evacuating livestock.

In India, there are many sectors where enhancements are limited for accurate predictions and for the classification of factors that affect the productivity of agriculture. This research aims to propose and establish an automated system for forecasting agriculture productivity which depends on various factors like temperature, humidity, wind speed, etc (Bhelawe et al., 2014; Kumar Bhuarya et al., 2015; Kumar Markam et al., n.d.).

5. Objectives of Research

The research seeks to understand the Indian agriculture system with respect to the following proposed objectives:

- To conduct the literature survey on agricultural productivity predictions
- To identify and analyze agro-climatic factors affecting agricultural productivity
- To explore and evaluate various machine learning techniques for predicting agricultural productivity based on identified factors
- To develop a model for the prediction of the agricultural productivity
- To compare the performance of different machine learning techniques

6. Proposed Model for Productivity Prediction

Figure 3 shows the basic workflow of the proposed model.

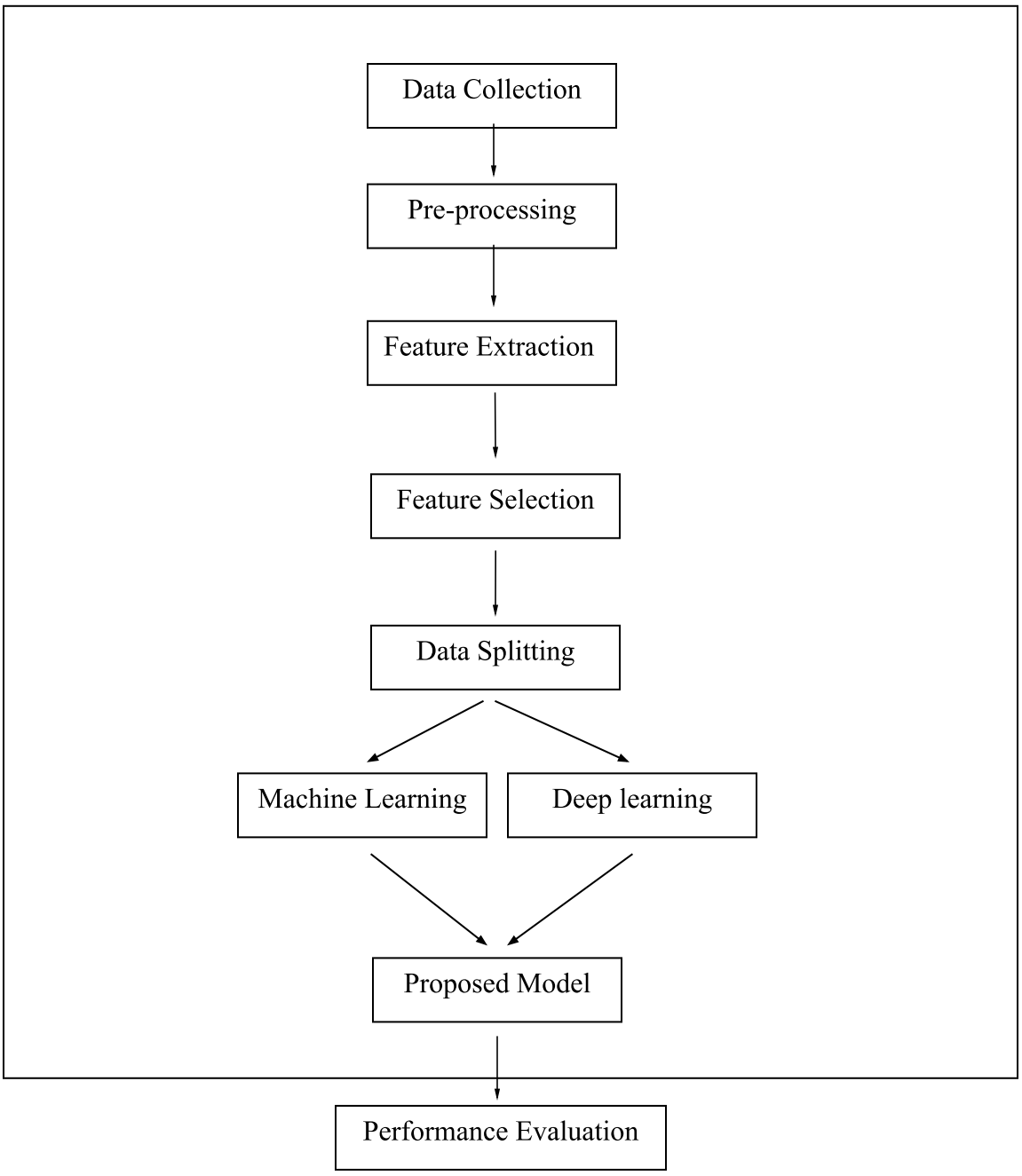

Figure 3. Proposed model workflow

Data Collection

The meteorological data for this work is gathered from an agriculture research centre located in Surguja, Chhattisgarh, India. Established methods were used for collecting data to ensure accuracy and reliability.

Preprocessing

Preprocessing will be done to prepare, clean, and transform the raw dataset into the required structured data that will be used for further analysis.

Feature Extraction and Selection

Feature extraction will be used to transform the dataset into a new representation by selecting relevant information while discarding less important information. Whereas feature selection will be applied to select the most relevant parameters from the original dataset.

Machine Learning/ Deep Learning Techniques

There are various ML/DL techniques that are going to be used in the dataset for the predicting the agricultural productivity based on the identified factors like KNN, decision trees, SVM, neural networks, Gradient boost etc.

Proposed Model

The proposed model will combine the ML/DL techniques to create a hybrid model for the better prediction of agricultural productivity based on the agro-climatic data.

Performance Evaluation

In this step, the performance of various models will be evaluated and analyzed to identify the most accurate and reliable model for predicting agricultural productivity based on the given dataset.

7. Expected Outcome of the Research

This study is an attempt to establish an automated agriculture system for rural areas where proper facilities are not present to predict and classify various factors affecting agriculture in terms of quantitative and qualitative products. This study will create an efficient and advanced system with the help of ML/DL models for agriculture productivity predictions that can enhance accuracy and increase crop yields. This system is an attempt to optimize resource utilization and monitor agriculture productivity factors. The findings of this study will definitely establish a better automated system that will enhance overall agriculture productivity.

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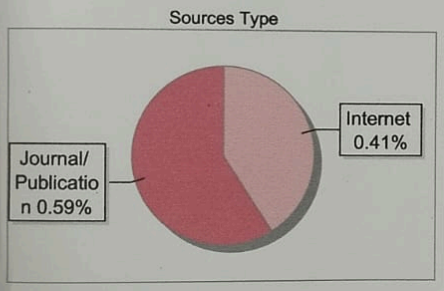

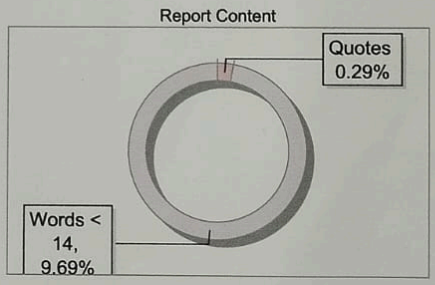

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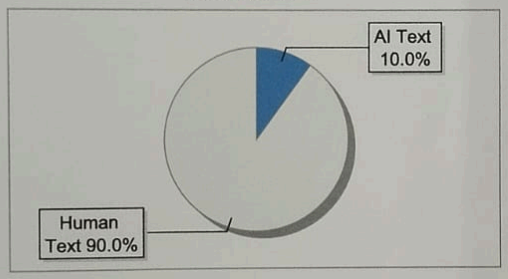

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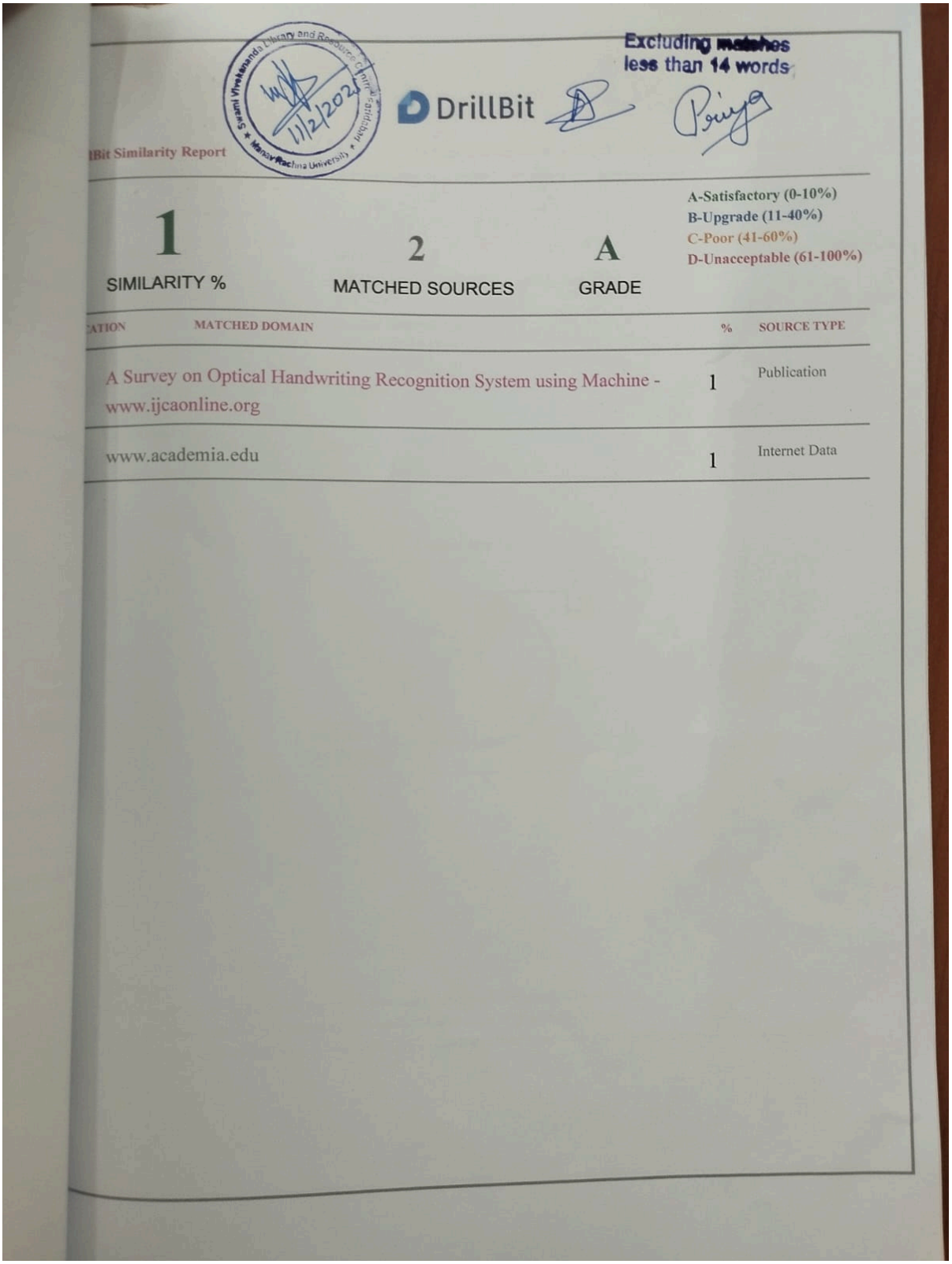

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